FEATURES OF MAGNETO-OPTICAL RESPONSE OF NANOSTRUCTURES FORMED IN VARIOUS REGIMES OF ION SURFACE TREATMENT

Prokaznikov A.V.[1], Paporkov V.A.[2], Chirikov V.A.[2]

1. Valiev Institute of Physics and Technology, RAS, Yaroslavl Branch (prokaznikov@mail.ru; WhatsApp:+7-961-023-83-75)
2. Yaroslavl State University named after P.G. Demidov

ABSTRACT. Experimental, technological and theoretical regularities are investigated that are connected with formation and variation of position of vortex magnetic structures depending on external applied magnetic field. It was demonstrated by means of micromagnetic simulations that the position of magnetic vortex on a cylindrical surface is controlled by external magnetic field. Magnetic vortex can be located on the base as well as on the side of cylindrical structures depending on the system parameters. Investigated effect can be used by magnetic memory creation on the base of structures with magnetic vortices.

INTRODUCTION

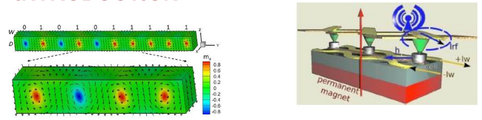


Figure 1. The scheme of functioning of race-track memory. It is ferromagnetic linear structure with the data that are coded as regions of magnetic domains or vortices along a nanowire.

EXPERIMENTAL PART

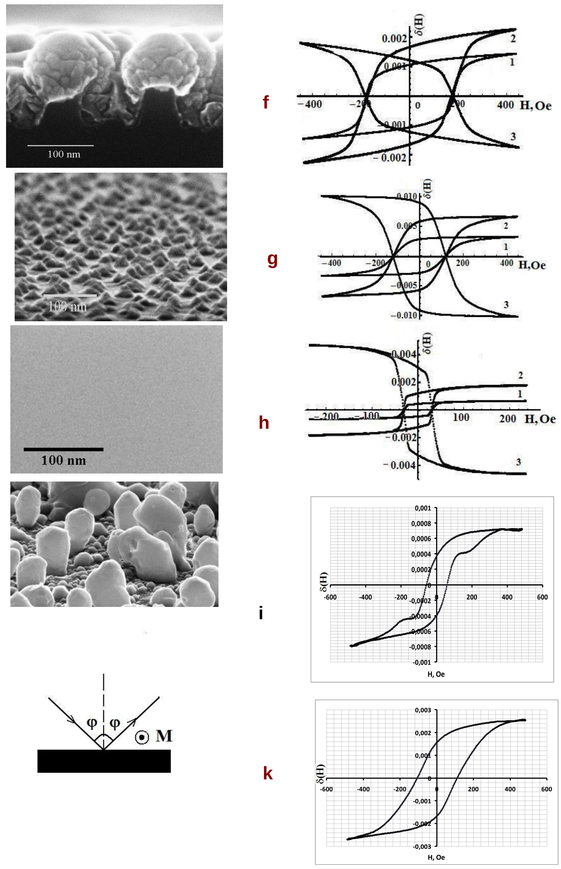


Figure 2. Structures on the base of covered on top by cobalt silicon nanostructures after sputtering of Co (sample 1) – (a). Structure with cobalt nanofilm on the base of anodized aluminum on silicon substrate (sample 2) – (b). Structure with homogeneous Co layer on silicon (sample 3) – (c).
Sample PbSe after treatment in Ar+ plasma during 4 minutes – (d).
The scheme of experiment in configuration of transverse magnetic Kerr effect (TMOKE) – (e). Right (f, g, h) are corresponding TMOKE dependencies δ(H) for λ = 633 nm and incident angles: **25° (1), 40° (2), 75° (3);** for PbSe sample: **52.5° – (i), 65° – (k).**

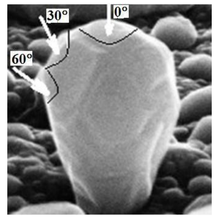


Figure 3. Separate element of PbSe nanostructure and corresponding incident angls of radiation

SIMULATION PART

Simulations on the base of Landau-Lifshitz equations

$$\frac{d\vec{M}}{dt} = -\gamma\vec{M}\times\vec{H}_{eff} - \frac{\gamma\alpha}{M_s}\vec{M}\times\left(\vec{M}\times\vec{H}_{eff}\right)$$ - Landau-Lifshitz equation

$$\vec{H}_{eff} = -\mu_0^{-1}\,\partial E/\partial\vec{M}$$

$$E = -J\sum_{\langle i,j\rangle}\vec{M}_i\cdot\vec{M}_j + \sum_{\langle i,j\rangle}D_{ij}\left(\vec{M}_i\times\vec{M}_j\right) - \mu_0\vec{H}\sum_i\vec{M}_i - \frac{1}{2}\mu_0\sum_i\vec{M}_i\cdot\vec{H}_d$$

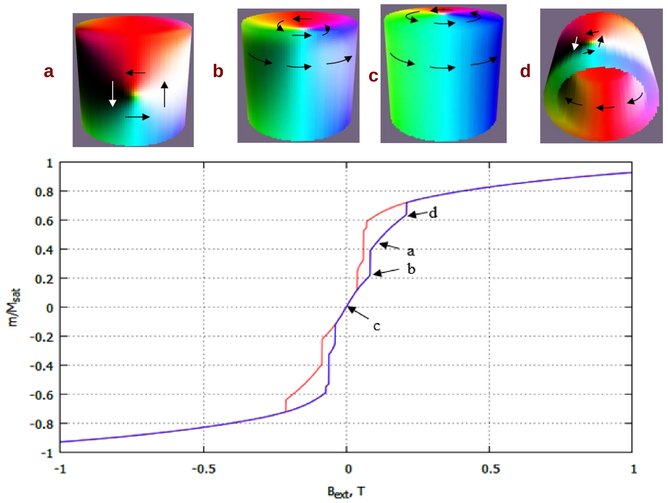
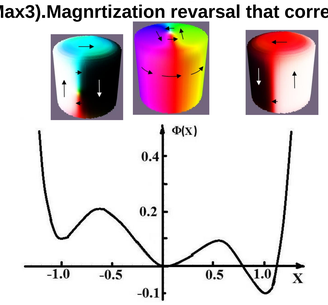


Figure 4. **Vortex magnetic structure on cylindrical surface with flat top without anisotropy (a-d) against applied magnetic field (simulation in MuMax3).Magnrtization revarsal that corresponds to the structures on (a-d).**



$$\Phi(m) = \frac{1}{2}a(T)m^2 + \left(\frac{1}{4}b - \frac{\lambda^2}{2K}\right)m^4 + \frac{1}{6}cm^6$$

$$\left(\frac{1}{4}b - \frac{\lambda^2}{2K}\right) < 0$$

Figure 5. Thermodynamic potential

Two-soliton approximation for skyrmion solution

$$\theta(\rho,c,w) = \begin{cases}\sum_{+,-}\left[\arcsin\left(th\left(\frac{-\rho\pm c}{w/2}\right)\right)\right]+\pi, & B_z>0\\ \sum_{+,-}\left[\arcsin\left(th\left(\frac{-\rho\pm c}{w/2}\right)\right)\right], & B_z<0\end{cases}$$

$$w = 2\cdot\sqrt{\frac{A_{ex}}{K_{eff}+M_sB/2}}\,c = \frac{w}{2}\operatorname{arcsin h}\left(\sqrt{\frac{2K_{eff}}{M_sB}}\right)$$

$$\rho = \sqrt{x^2+y^2}$$

$$\vec{S}(x,y) = \begin{pmatrix}-\sin\left[\theta(\rho,c,w)\right]\cdot\left(x/\rho\right)\\ -\sin\left[\theta(\rho,c,w)\right]\cdot\left(y/\rho\right)\\ \cos\left[\theta(\rho,c,w)\right]\end{pmatrix}$$

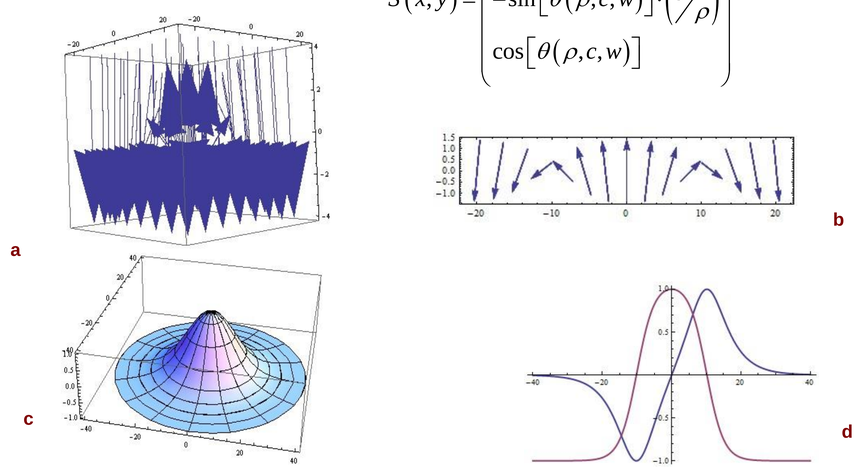


Figure 6. General view of three dimensional image of 20×20 nm² region, which corresponds to the presence of magnetic vortex. The a – general view of magnetic moments orientations, b – cross section of magnetic moments orientations, c – projection of magnetic moments on OZ axis, d – dependencies of magnetic moments projection on OZ (pink) and OX axis.

CONCLUSIONS

1. **Normalized magneto-optical hysteresis loops, that were obtained at different incident angles, for the structures with sizes less t**
2. **For nanostructures on the base of PbSe at determined parameter values magneto-optical loops were obtained that are typical t**
3. **For the sub-micron structures the displacement of hysteresis loops was observed which can be connected with the influence o**
4. **Two-soliton solutions approximations for skyrmion solution were obtained.**
5. **The position of magnetic vortex on a cylindrical surface depends on external magnetic field value.**
6. **Magnetization reversal at the presence of magnetic vortices occurs with less losses of energy then without magnetic vortices ap**